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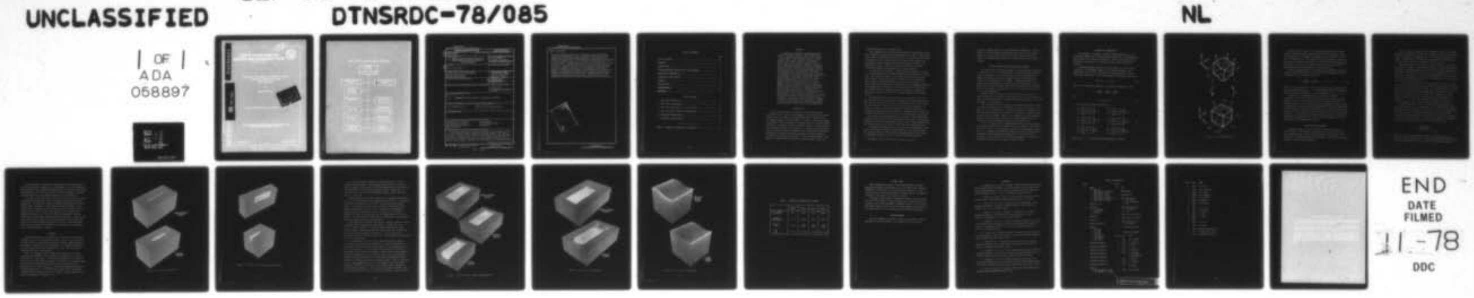

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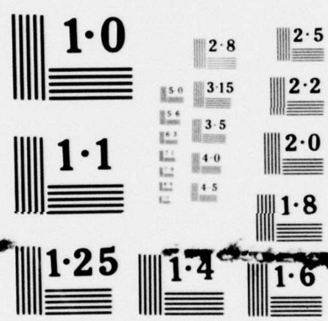

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BOUNDARY-FITTED COORDINATE SYSTEMS FOR THREE-DIMENSIONAL REGIONS CONTAINING SHIP-LIKE BODIES

by

Roderick M. Coleman

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COMPUTATION, MATHEMATICS AND LOGISTICS DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

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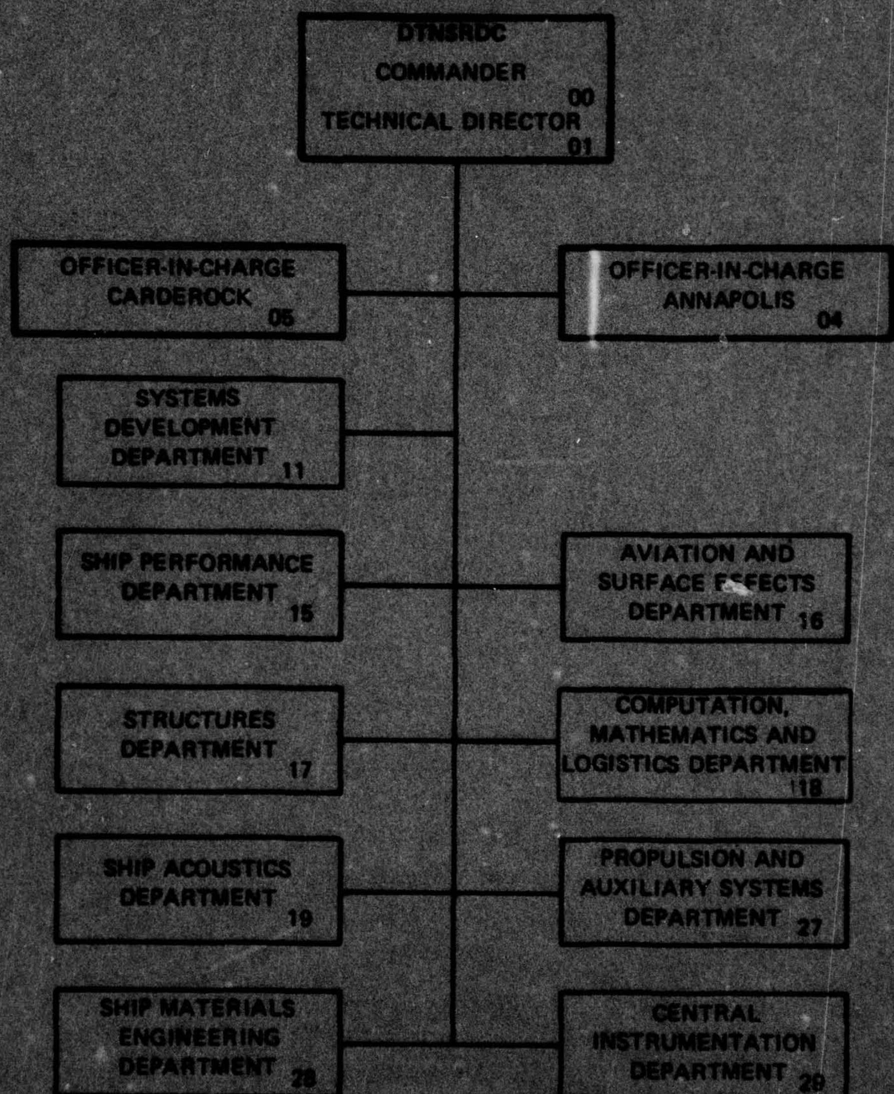

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 DTNSRDC-78/085	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 BOUNDARY-FITTED COORDINATE SYSTEMS FOR THREE-DIMENSIONAL REGIONS CONTAINING SHIP-LIKE BODIES		5. TYPE OF REPORT & PERIOD COVERED 9 Interim Report, Oct 1977 - Apr 1978
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Roderick M. Coleman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 61153N Task Area SR0140301 Work Unit 1-1808-010
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 11 September 1978
		13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

12 25 p.

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

16 SR01403 17 SR0140301

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Boundary-Fitted Coordinates
Three-Dimensional Regions
Partial Differential Equation
Finite-Difference
Finite-Element
Boundary-Value Problem
Fluid Dynamics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A method for numerically generating boundary-fitted coordinate systems for three-dimensional regions containing ship-like bodies is the subject of this report. This procedure involves a transformation which maps the region of interest in physical space onto a region in computational space where a uniform grid is defined. The result is a curvilinear coordinate system in the physical region having coordinate lines coincident with all boundary contours.

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The finite-difference solution of a system of partial differential equations corresponding to a physical problem can be obtained on the regular mesh in the computational range space. Alternatively, the boundary-fitted mesh in the physical domain space may be used as the basis of a finite-element scheme for this solution. The mapping, which is a generalization of conformal mapping, is found as the solution of a system of elliptic partial differential equations with appropriate boundary conditions. A general description of the technique is presented along with the mathematical formulation of the underlying boundary-value problem. Also included are methods of transformation control which are needed for developing grid systems suitable for numerical solutions of problems in fields such as fluid dynamics. Examples of several transformations are discussed in terms of their associated physical and computational regions and the elliptic systems used for their generation.

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ABSTRACT

A method for numerically generating boundary-fitted coordinate systems for three-dimensional regions containing ship-like bodies is the subject of this report. This procedure involves a transformation which maps the region of interest in physical space onto a region in computational space where a uniform grid is defined. The result is a curvilinear coordinate system in the physical region having coordinate lines coincident with all boundary contours. The finite-difference solution of a system of partial differential equations corresponding to a physical problem can be obtained on the regular mesh in the computational range space. Alternatively, the boundary-fitted mesh in the physical domain space may be used as the basis of a finite-element scheme for this solution. The mapping, which is a generalization of conformal mapping, is found as the solution of a system of elliptic partial differential equations with appropriate boundary conditions. A general description of the technique is presented along with the mathematical formulation of the underlying boundary-value problem. Also included are methods of transformation control which are needed for developing grid systems suitable for numerical solutions of problems in fields such as fluid dynamics. Examples of several transformations are discussed in terms of their associated physical and computational regions and the elliptic systems used for their generation.

INTRODUCTION

The increasing usage of boundary-fitted (surface-oriented) coordinates in the field of fluid dynamics is indicative of this technique's value as a numerical problem-solving tool. Typically, the investigator wishes to study the flow of a fluid in a particular region by analyzing a partial differential equation subject to certain boundary conditions. The proper choice of coordinate system is often crucial to the successful solution of the problem. As a result, much use has been made of "natural" coordinate systems such as cylindrical and spherical coordinates, although the practical usefulness of such systems is restricted to a few specialized cases. For any specific geometry, the method of boundary-fitted coordinates creates a system in which the

surfaces themselves are coordinate lines.

The procedure involves a numerically generated transformation which maps the physical region under consideration onto a simpler computational region where a uniform mesh has been defined. In effect two grid systems are produced by this transformation: the boundary-fitted mesh in the domain space and the regular mesh in the range space. Either of the meshes may be used to compute the numerical solution to a partial differential equation corresponding to a physical problem.

In obtaining this solution, a finite-difference approach must take into account variations in the mesh upon which the computations are to be done. The numerical scheme is often complicated by these variations which normally occur in zones where increased accuracy is desired or where irregularly-shaped boundaries are resolved. If, however, the calculations are performed on the regular mesh in the computational space, these complications disappear since the mesh spacing is uniform there. This usually leads to a simpler numerical treatment even though the equation of ultimate interest may be somewhat altered by the transformation.[1*]

Calculations may also be carried out in the physical region with the grid points there being taken as the nodes of a finite-element mesh. The important aspect here is not the transformation itself, but the fact that the network of mesh points in the physical space conforms to the boundary contours. Used in this manner, the numerically generated coordinate technique provides an efficient, automatic means of producing a boundary-fitted grid system suitable for finite-element calculations.[2]

This numerical mapping technique was extended to three-dimensional domains in earlier work by Ghia[3] and Mastin.[4] The purpose of the present research is to present some examples of new types of transformations that are proving useful in the study of fluid flow about ship-like bodies.

As expected, the generalization from two to three dimensions constitutes a considerable increase in the complexity of the entire process. The increased computer time and memory requirements have been overcome to some extent through the use of the Texas Instruments Advanced

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*A complete listing of references is given on page 17.

Scientific Computer (TIASC) at the Naval Research Laboratory. Since the number of possible mapping configurations also rises with the number of dimensions, the experienced user of this approach should be able to produce a coordinate system suitable for practically any flow geometry of interest.

FINITE-DIFFERENCE APPLICATION TO FLOW PROBLEMS

The body-fitted coordinate technique has several features which make it attractive for use in conjunction with a finite-difference scheme for fluid flow problems. One of these features is the three-dimensional mapping capability as opposed to complex variable methods which are limited to two-dimensional flow problems. Although the numerically generated transformations are not conformal (the orthogonality of coordinate lines is not preserved), there is no real problem since orthogonality is not required at boundaries to obtain an accurate representation of the normal derivative.[5]

Another important property is that all surface contours in the physical region are coincident with coordinate surfaces. This allows for the accurate representation of boundary conditions regardless of the shape and number of bodies present.

All calculations, both to generate the coordinate system and to solve the equations governing the flow problem, are done on the fixed, uniform mesh in the transformed region. Since the mesh must be recomputed whenever the boundaries change or deform, the coefficients of the difference operators may also change. However, this updating of the transformation required a relatively small portion of the total computing time in a recent study of two-dimensional unsteady free surface flow.[1]

Also, coordinate lines in the physical region may be concentrated in areas where more resolution or higher accuracy is desired. This concentration or control of the coordinate lines can be accomplished in several ways: 1) by changing the mapping configuration itself, 2) by varying the underlying elliptic generating equations, and 3) by altering the distribution of grid points on the physical boundaries. A discussion of coordinate system control is found in a later section.

MATHEMATICAL FORMULATION

The technique of numerical coordinate system generation for two-dimensional regions and a finite difference scheme for its implementation were presented in a previous publication.[6] Here we develop the three-dimensional counterpart in a slightly different manner using tensor notation.

A three-dimensional region of arbitrary shape, R, is to be transformed into the rectangular region, R', as shown in Figure 1. For convenience, let x^i be the usual Cartesial coordinates and u^i be the transformed coordinates. The u^i are obtained as solutions of the system

$$\nabla^2 u^i = P_i, \quad i = 1,2,3 \tag{1}$$

where ∇^2 is the Laplacian operator in Cartesian coordinates, so that

$$\nabla^2 = \frac{\partial^2}{\partial x^1 \partial x^1} + \frac{\partial^2}{\partial x^2 \partial x^2} + \frac{\partial^2}{\partial x^3 \partial x^3}$$

and

$$P_i = P_i(u^1, u^2, u^3) \tag{2}$$

The Dirichlet boundary conditions are

$$\left.\begin{aligned} u^1 &= \text{const.} = c_1 \\ u^2 &= u_1(x^1,x^2,x^3) \\ u^3 &= u_2(x^1,x^2,x^3) \end{aligned}\right\} \text{on } S_1 \qquad \left.\begin{aligned} u^1 &= \text{const.} = c_4 \\ u^2 &= u_7(x^1,x^2,x^3) \\ u^3 &= u_8(x^1,x^2,x^3) \end{aligned}\right\} \text{on } S_4$$

$$\left.\begin{aligned} u^1 &= u_3(x^1,x^2,x^3) \\ u^2 &= \text{const.} = c_2 \\ u^3 &= u_4(x^1,x^2,x^3) \end{aligned}\right\} \text{on } S_2 \qquad \left.\begin{aligned} u^1 &= u_9(x^1,x^2,x^3) \\ u^2 &= \text{const.} = c_5 \\ u^3 &= u_{10}(x^1,x^2,x^3) \end{aligned}\right\} \text{on } S_5 \tag{3}$$

$$\left.\begin{aligned} u^1 &= u_5(x^1,x^2,x^3) \\ u^2 &= u_6(x^1,x^2,x^3) \\ u^3 &= \text{const.} = c_3 \end{aligned}\right\} \text{on } S_3 \qquad \left.\begin{aligned} u^1 &= u_{11}(x^1,x^2,x^3) \\ u^2 &= u_{12}(x^1,x^2,x^3) \\ u^3 &= \text{const.} = c_6 \end{aligned}\right\} \text{on } S_6$$

where S_1, S_2, ..., S_6 are the surfaces indicated in Figure 1.

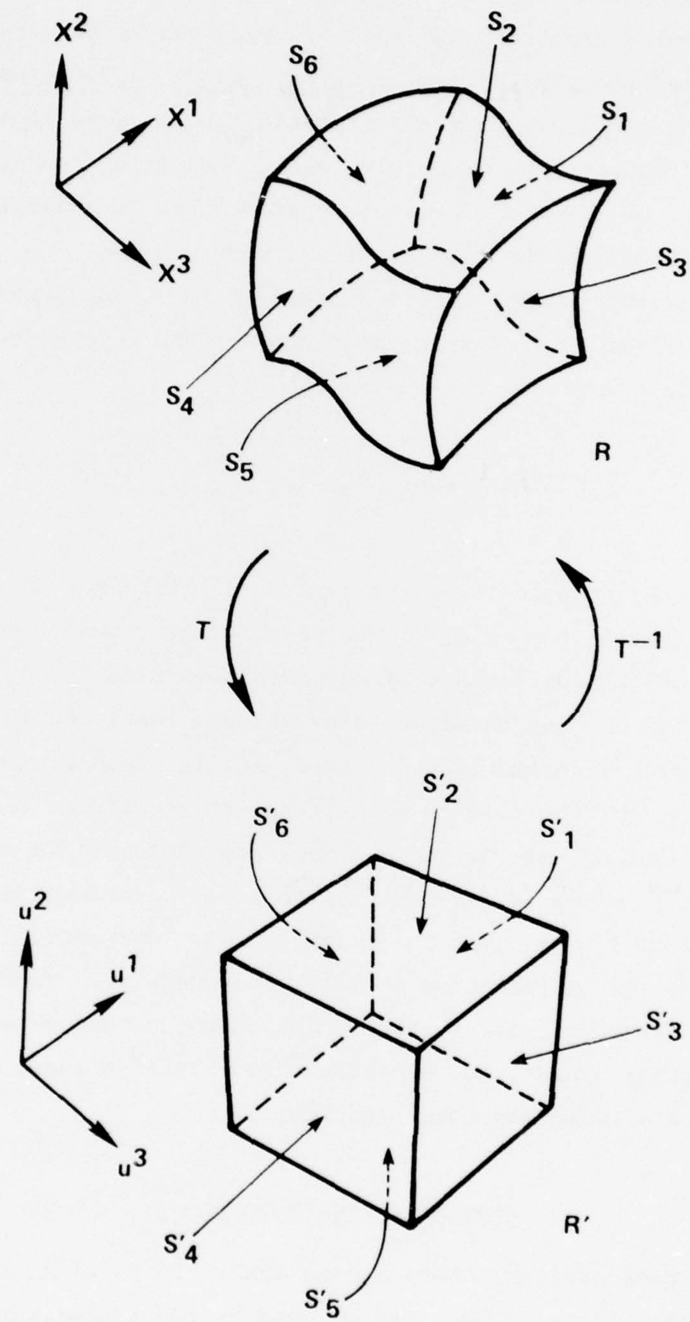

Figure 1 - Basic Transformation

There are several aspects of this general boundary-value problem which are somewhat arbitrary and must be specified by the user. These are the shape of the computational region, the P_i in Equation (2) and the u_i in Equations (3). This specification can be made in a manner that will greatly influence the properties of the resulting coordinate system. The ability to control the coordinate system which is generated is an important topic and is the subject of the next section.

Since all computations are to be done in the transformed region R', we must interchange the roles of the dependent and independent variables in Equation (1). The inverted system is

$$g^{\lambda\mu} \frac{\partial^2 x^i}{\partial u^\lambda \partial u^\mu} + P_\nu \frac{\partial x^i}{\partial u^\nu} = 0, \qquad i = 1,2,3 \tag{4}$$

where $g^{\lambda\mu}$ are the components of the contravariant tensor associated with the Euclidean metric tensor $g_{\lambda\mu}$. The transformed boundary conditions are simply the physical coordinates of the mesh points on $S_1, S_2, \ldots, S_6$.

Equation (4) is approximated using second-order, central differences for all derivatives involved, and the resulting difference equations solved on the uniform mesh in the computational region. The difference equations and iteration scheme are discussed in detail for the two-dimensional system in earlier publications.[1,6] Accelerated Gauss-Seidel iteration was used to produce the examples in this report, although this may not be the most efficient method for computers with vector processing capability. A vectorizable iteration method which sweeps the grid points in an alternating manner, the so-called "red-black" method, was used by Haussling[7] for a two-dimensional problem.

COORDINATE SYSTEM CONTROL

As mentioned earlier, there are several methods of coordinate system control. These methods can be used by the researcher to tailor the coordinate system to his particular problem. Although there is a great deal of flexibility inherent in this method, care must be exercised in order to obtain a proper mapping.

The first way of influencing the coordinate system is by changing the mapping configuration itself. For simplicity, the physical domain in Figure 1 was taken as a deformed cube. If R had been less regular in shape, a computational region made up of more than one cube might have been necessary to generate a desirable coordinate system.

The second area of flexibility lies in the elliptic equations that are taken as the basis of the generating system. Although any equation exhibiting an extremum principle may be used, the Poisson equation seems to suffice in most cases since we have the P_i in Equation (2) at our discretion. The ability to vary these non-homogeneous terms provides us with an effective means of controling the distribution of the coordinate lines in the physical region R.

In several earlier works,[1,7,8] the inhomogeneous terms were chosen such that the coordinate lines were attracted to or repelled from certain specified points in the physical region. This approach, while effective, proved to be both tedious and time-consuming. Often, the procedure consisted of making an initial estimate of the parameters in the P_i terms, generating a mesh with these parameters, and displaying it graphically. This process was repeated, with slight changes in the control parameters, until a suitable transformation was produced.

Thompson[9] presented a method of choosing the inhomogeneous terms so that the spacing of the coordinate lines on the boundary is maintained throughout the entire region. This choice of source terms was effective in creating meshes for problems involving free surfaces with small elevations. Large amplitude waves, however, are not resolved satisfactorily by this Poisson system. A modification of Thompson's derivation leads to the following definition of the P_i of Equation (2):

$$P_i = \left. \frac{-\partial^2 x^i/\partial u^i \partial u^i}{(\partial x^i/\partial u^i)^3} \right|_{u^i = c_i} \tag{5}$$

where $u^i = c_i$ are the boundaries on which the x^i spacing is to be preserved. These source terms have produced improved coordinate systems for flow regions with both large and small free surface elevations.

The third means of coordinate system control is the specification of the two non-constant coordinates, u_i in Equations (3), on the boundaries. The user does not have complete freedom here since this input characterizes the boundaries, but in most cases there is sufficient leeway to provide a coordinate system with the desired properties on the boundaries.

It is well to note that often the most satisfactory coordinate system is obtained when these three methods of control are used in the proper combination. One might first choose a mapping configuration that has the desired general properties. Some properties considered might be, for example, which coordinate will be constant along each boundary, how many coordinate lines will intersect each boundary, and the shape of the computational region, etc. After the general configuration has been determined, the generating equations must be decided upon. A good initial choice seems to be a system of Poisson equations with source terms that preserve the boundary spacing throughout the region as described above. Finally one can adjust the distribution of grid points on the boundaries until a suitable mapping is achieved.

EXAMPLES

As indicated earlier, the flexibility of the body-fitted coordinate technique is one of its most important assets. There is no restriction to simple regions, although multi-connected and other complex geometries may require a combination of simple mappings. The examples presented in this section were calculated to demonstrate a few of the many possible transformations that can be produced.

First, we consider a physical domain which contains a thin body intersecting one boundary. This example may be thought of as a model of a ship hull in a free surface. The natural transformation for a body of this shape is one which maps the object to a portion of a coordinate plane. Figure 2 shows the body-fitted coordinate system in physical space generated with zero source terms, P_i, and the corresponding uniform mesh in computational space. Two cross-sectional views of this curvilinear coordinate system are shown in Figure 3. (Table 1 gives a summary of the computer requirements for Figures 2 - 6.)

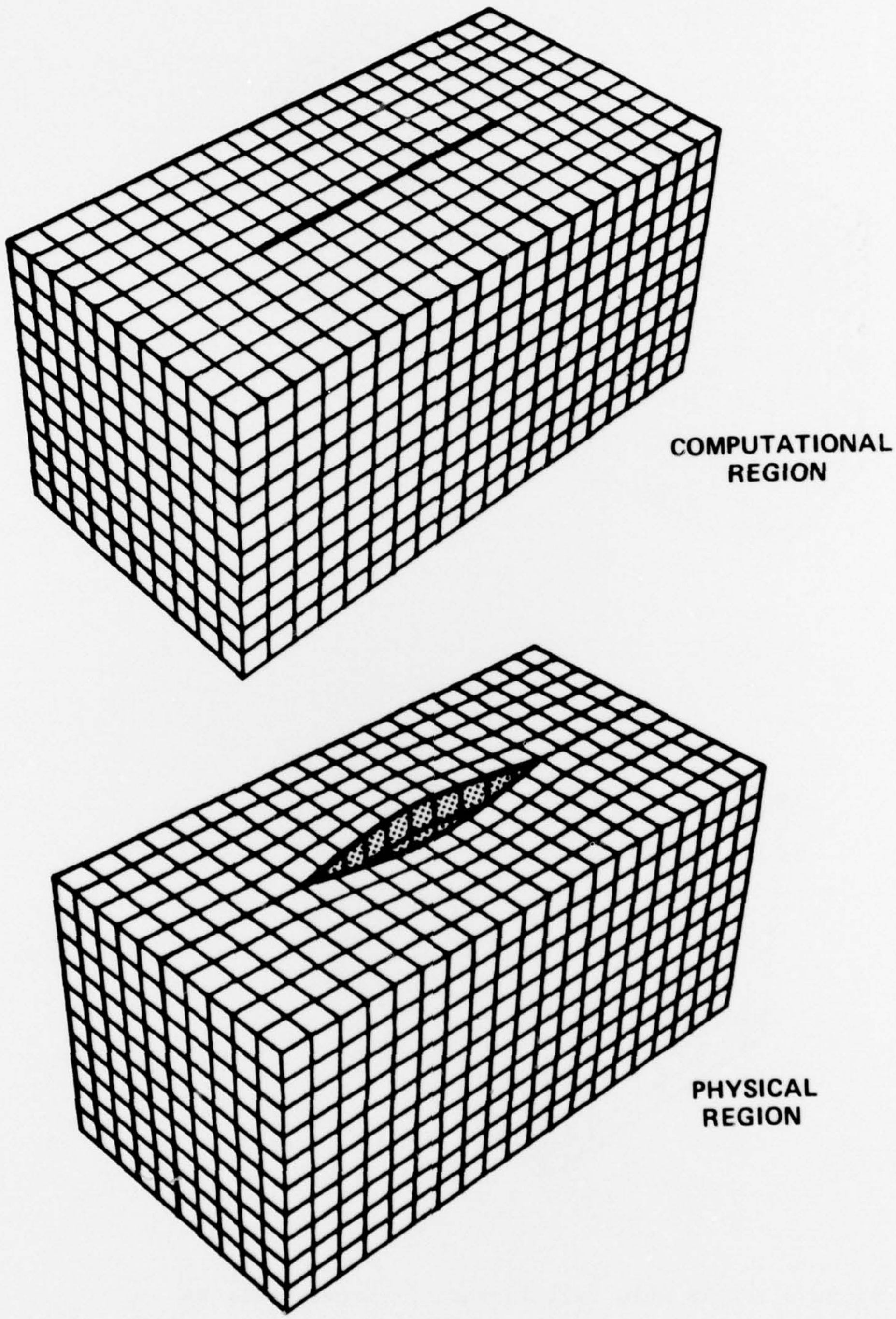

Figure 2 - Thin Ship Transformation

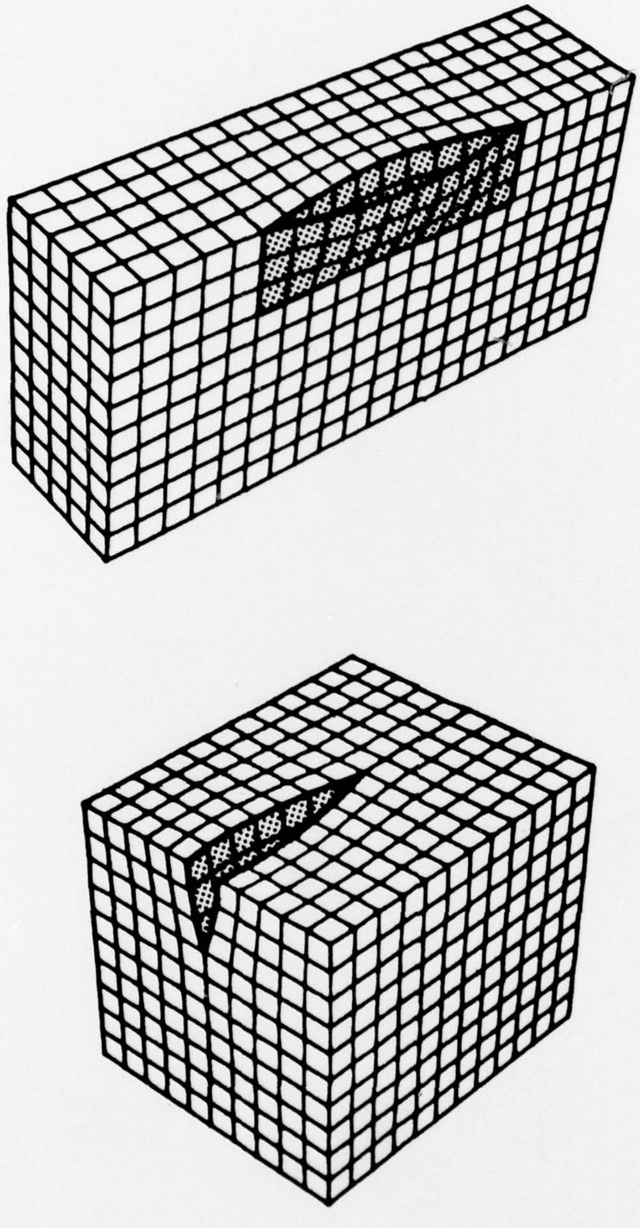

Figure 3 - Thin Ship Transformation--Cross Sections

In the next example we generate a grid system about a circular cylinder of finite length. This mapping provides us with a coordinate system in physical space which is quite different from the usual cylindrical coordinates. For illustrative purposes, Figure 4 shows only the lower half of the physical and transformed regions. Again, the source terms, P_i, are zero.

To demonstrate the multi-body capability, we consider another ship-like form in conjunction with two smaller objects close by. In generating this single transformation we must take into account three separate bodies. The largest of the three has a circular cross-section with a rounded, sloping bow and a flat stern. This portion is handled in a manner similar to that used in the second example. The two smaller bodies at the ship's stern are thin and are transformed as in the first example. The mesh systems in physical and computational space generated with zero source terms are shown in Figure 5.

As an example of coordinate line control, consider a physical region simulating a fluid bounded by straight walls, a bottom, and a free surface. Figure 6 shows two coordinate systems generated for such a physical region: one generated with zero source terms and one generated with source terms as given in Equation (5). We see that the non-homogeneous system has produced a mesh with a more desirable configuration near the curved surface.

It is appropriate at this point to mention the role of computer aided graphics in numerical mesh generation. Usually, the process of obtaining a suitable coordinate transformation for a specific problem is one of trial and error. Interactive plotting routines are useful in shortening the time needed by helping to locate errors in input boundary data and by displaying the final output. The use of these automated graphing techniques has proven to be practically indispensible in the analysis of numerically generated coordinate systems. This is especially true for three-dimensional systems. The figures in this report were generated by IMAGE,[10] an interactive data display package available in the Computation, Mathematics, and Logistics Department of DTNSRDC. For details on the use of this and other similar programs, contact Code 1843.

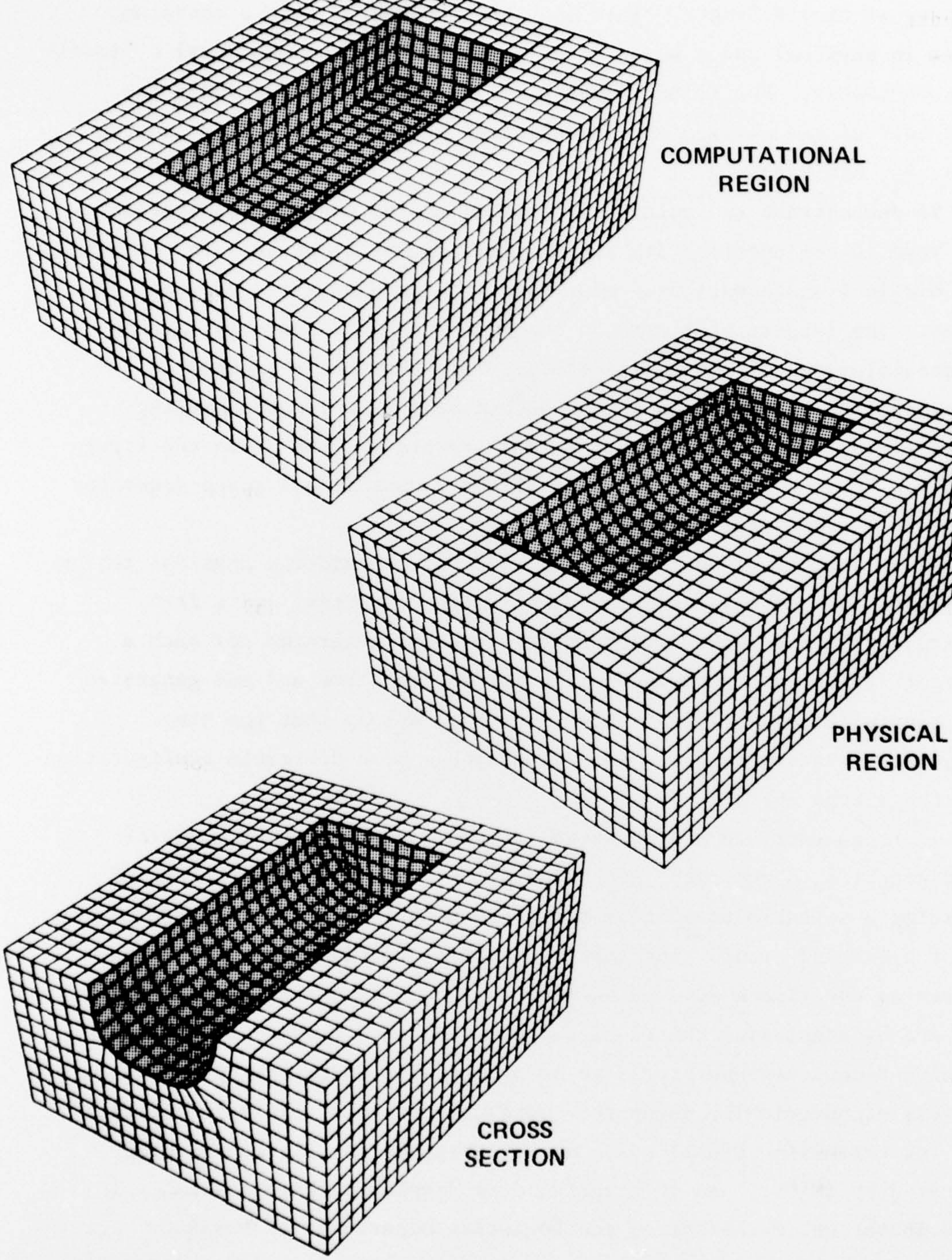

Figure 4 - Finite Circular Cylinder Transformation

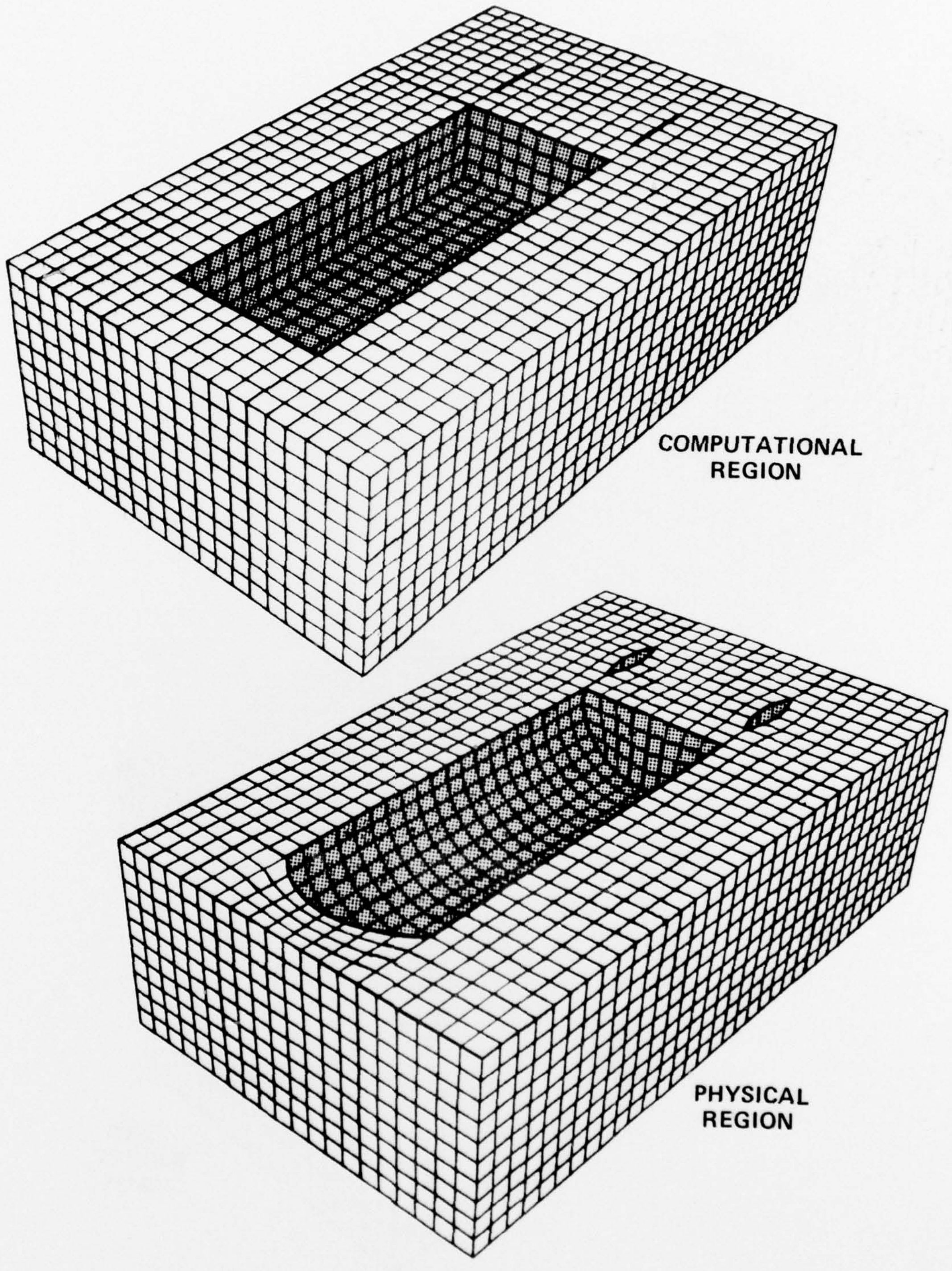

Figure 5 - Multi-Body Transformation

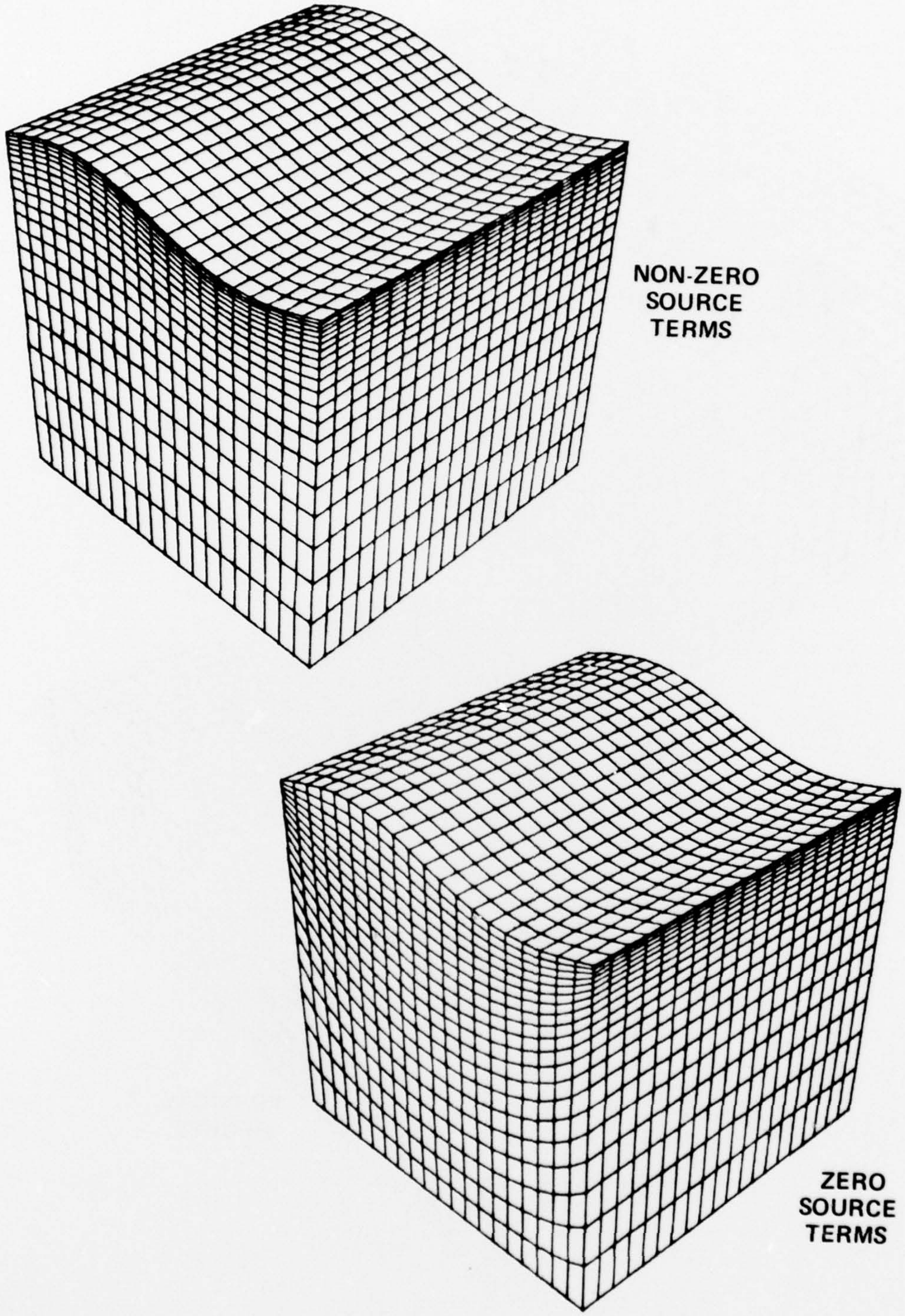

Figure 6 - Coordinate System Control

TABLE 1 - COMPUTER REQUIREMENTS FOR FIGURES

	Figures 2 and 3	Figure 4	Figure 5	Figure 6
Total Number of Points	2541	6629	7553	9261
Memory Requirements	131 K	204 K	222 K	236 K
Computer Used	TIASC	CDC 6400	CDC 6400	CDC 6400
CPU Time	7.1 sec	20.9 sec	22.3 sec	34.2 sec

FUTURE PLANS

Three-dimensional versions of the boundary-fitted coordinate generating programs are operational on the CDC 6000 series computers at DTNSRDC and on the TIASC at the Naval Research Laboratory. Work is continuing on refining these programs in preparation for the numerical solution of free surface and ship wave problems.

Problems currently under investigation include 1) the non-linear effects of water waves, 2) large amplitude waves nearing the point of breaking, and 3) ships undergoing a slamming motion in a free surface. Most likely these and other large fluid flow problems will be solved on the TIASC because of its large memory and vectorization capability.

ACKNOWLEDGMENTS

The author wishes to thank Mrs. Joanna W. Schot and Dr. Henry H. Haussling for their assistance in the preparation of this report.

REFERENCES

1. Haussling, H.J. and R.M. Coleman, "Finite-Difference Computations Using Boundary-Fitted Coordinates for Free-Surface Potential Flows Generated by Submerged Bodies," Proc. Second International Conf. on Numerical Ship Hydrodynamics, Univ. of Calif. at Berkeley (September 1977).

2. Zarda, P.R. and M.S. Marcus, "Finite Element Solutions of Free-Surface Flows," NASA Conference Publication 2018, pp. 27-52 (1977).

3. Ghia, U. et al., "Use of Surface-Oriented Coordinates in the Numerical Simulation of Flow in a Turbine Cascade," Lecture Notes in Physics, Vol. 49, pp. 197-204 (1976).

4. Mastin, C.W. and J.F. Thompson, "Transportation of Three-Dimensional Regions onto Rectangular Regions by Elliptic Systems," Numerische Mathematik, Vol. 29, pp. 397-407 (1978).

5. Thompson, J.F. et al., "Automatic Numerical Generation of Body-Fitted Curvilinear Coordinate System for Field Containing Any Number of Arbitrary Two-Dimensional Bodies," Journal of Computational Physics, Vol. 15, pp. 299-319 (1974).

6. Coleman, R.M., "NUMESH: A Computer Program to Generate Finite-Difference Meshes for Arbitrary Doubly-Connected Two-Dimensional Regions," Report DTNSRDC/CMLD-77/05 (March 1977).

7. Haussling, H.J., "Boundary-Fitted Coordinates for Accurate Numerical Solution of Multi-Body Flows," accepted for publication in Journal of Computational Physics (1978).

8. Thompson, J.F. et al., "Use of Numerically Generated Body-Fitted Coordinate Systems for Solution of the Navier-Stokes Equations," Proc. of AIAA 2nd Computational Fluid Dynamics Conf., Hartford, CT (1975).

9. Thompson, J.F. and S.P. Shanks, "Numerical Solution of the Navier-Stokes Equations for 2D Surface Hydrofoils," Report MSSU-EIRS-ASE-77-4, Engr. and Industrial Res. Station, Mississippi State Univ. (1977).

10. Haas, M.E. and M.B. Marquardt, "The Interactive IMAGE Display System," Report DTNSRDC/CMLD-78/07 (1978).

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